**CHEMICAL PROCESS SYSTEM MINIATURIZATION.** Robert S. Wegeng, Charles J. Call, M. Kevin Drost, Annalee Y. Tonkovich, P.O. Box 999, Pacific Northwest National Laboratory[1], Richland Washington, USA.

**Abstract:** The purpose of this presentation will be to describe the potential for the realization of compact chemical processing systems, exhibiting high process rates, using precision engineering techniques, originally developed for the electronics industry.

Researchers at the Pacific Northwest National Laboratory (PNNL) have successfully fabricated and tested a variety of microcomponents that perform many of the standard unit operations of interest for chemical processing systems. Microcomponents currently in various stages of development at PNNL include chemical reactors, heat exchangers, gas absorbers, liquid-liquid extractors, and microactuators for pumps, valves and compressors. In some cases, prototypes show the potential for high performance and capacity (throughput).

If successfully developed, microchemical systems may represent a new class of chemical process systems**.** As Figure 1 suggests, these systems will be more compact than conventional, "macro" chemical processing systems, and can exploit microscale phenomena, such as heat and/or mass transport, to significant advantage. In addition, systems composed of multiple units have the potential of providing high degrees of redundancy. Finally, their small size and weight should make them available for distributed/portable/mobile applications.

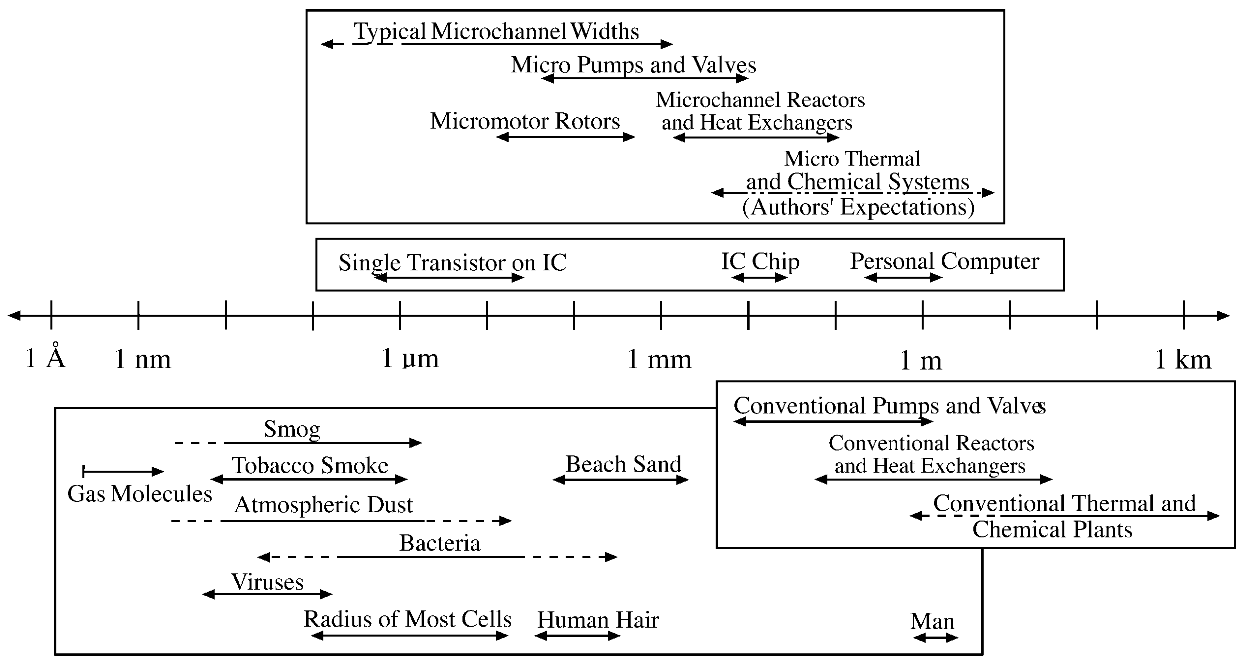


**Fig. 1.** Sizes/Characteristics of Microcomponents.

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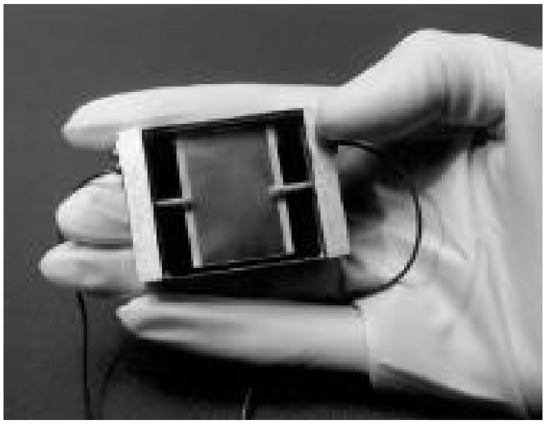

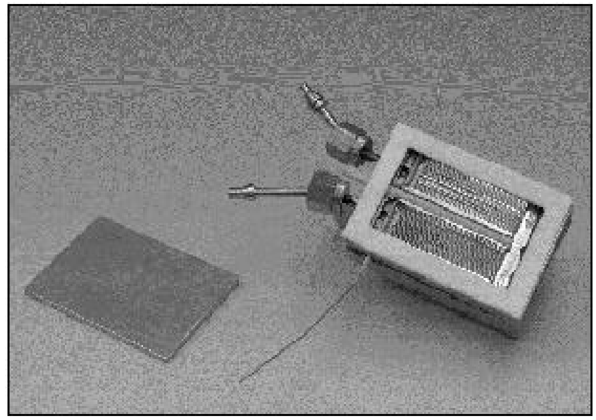

**Fig. 2 and Fig. 3.** Microchannel Heat Exchanger (left) and Microchannel Chemical Reactor (right).

Microchannel heat exchangers have exhibited high performance potential. In experimental investigations at PNNL, microchannel heat exchangers have provided high overall heat flux (e.g., 100 watts/cm$^2$) coincident with high heat tranfer coefficients (10,000 - 13,000 watts/m$^2$-C for liquid flow, and 30,000 - 35,000 watts/m$^2$-C for evaporating flow) and low pressure drops (less than a few pounds per square inch). Similar results have been observed for mass transport in microchannels.

Experiments have also included the integration of exothermic and endothermic microchannel chemical reactors with microchannel heat exchangers. Gas phase, catalytic, and plasma reactors have been investigated, with favorable results. For example, the reactor shown in Figure 3 and subsequent versions have been demonstrated as an integrated combustor/evaporator (boiler), successfully demonstrating high heat flux (e.g., greater than 50 watts/cm$^2$ with an overall energy conversion efficiency exceeding that of conventional, large-scale boilers (e.g., greater than 82%).

In another example, the catalytic, partial oxidation of methanol and butane has been successfully demonstrated in a proof-of-principle microchannel reactor system, with moderate to high syngas ($CO + H_2$) production rates. The interest here is to produce a hydrogen fuel stream for lightweight fuel cells, for man-portable and vehicular power generation. Compact chemical processing systems for environmental remediation and small heat pumps for portable and commercial/residential use are additional targeted applications.

Scaleup is intended to be provided through the incorporation of system architectures that accomodate large numbers of microcomponents working in parallel and in series. Such configurations should provide additional novel operating characteristics, such as enhanced reliability (through redundancy) and high turndown ratios with individual components continuing to operate at or near ideal operating conditions.

**References:** [1] Call, C. J., M.K. Drost, and R.S. Wegeng, “Combustion and Partial Oxidation in Compact Microchannel Reactors”, *A.I.Ch.E. 1996 Spring National Meeting*, New Orleans, Louisiana, February, 1996. [2] Cuta, J., W. Bennett, and C.E. McDonald, “Fabrication and Testing of Microchannel Heat Exchangers”, *SPIE Micromachining and Microfabrication ‘95 Conference Proceedings*, 1995. [3] Tonkovich, A.Y., C.J. Call, D. Jimenez, R.S. Wegeng, R., and M.K. Drost, “Microchannel Heat Exchangers for Chemical Reactors”, published in the *Proceedings of the 1996 National Heat Transfer Conference*, session on Heat Transfer Issues in Chemical Reactor Design and Operation, *AIChE*, August 1996. [4] Wegeng, R.S., C.J. Call, and M.K. Drost, “Chemical System Miniaturization,” presented at the Spring National Meeting of the AICHE, February 1996. Available on the World Wide Web at http://w3.pnl.gov:2080/transfer/tech/fliers/microfly.html.